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The Relationship between Roughness of Finished Wood Floors and Slip Resistance

Odnos između hrapavosti i klizavosti površinski obrađenih drvenih podova

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ABSTRACT • *The present study investigates the relationship between the roughness of beech wood and oak wood surfaces treated with oil and polyurethane coating and the slip resistance in dry, water-wet and oily conditions. Pendulum tests were conducted for slip resistance assessment, and roughness measurements were performed by stylus instrument using R_a, R_t, R_p, R_z and R_{sm} parameters for surface roughness evaluation. Slip potential in dry conditions was low for all finished wood floors studied. Contamination of the surface with water and oil reduced the slip resistance of finished oak and beech flooring. The strong negative correlation was found between slip resistance on dry finished flooring and roughness parameters R_a, R_z, R_t and R_p, and positive correlation between slip resistance on water-wet finished flooring and roughness parameters R_a, R_z, R_t and R_p. Moreover, the correlations between roughness parameters R_a, R_t, R_p and R_z and slip resistance were very similar, and the roughness parameters correlated more strongly with the slip resistance on dry and water-wet surfaces than with the slip resistance on oil-wet surface. Comparison of the slip potential classifications of finished wood floors based on pendulum data and based on R_z surface roughness parameters showed that in some cases the R_z parameter appeared to overestimate the slip potential of the floors in wet conditions. The results confirm previous research that roughness measurements should only be used as a guide and should not be used as the only indicator of the slip potential of wood flooring materials.*

Keywords: *slip resistance; surface roughness; finished wood floors; surface roughness parameters*

SAŽETAK • *U radu je istraživan odnos između hrapavosti bukovine i hrastovine površinski obrađenih uljem i poliuretanskim lakom i klizavosti suhe površine te površine na koju su se prolili voda i ulje. Klizavost površine određena je klatnom, a hrapavost joj je izmjerena kontaktnim uređajem uz pomoć parametara R_a, R_t, R_p, R_z i R_{sm} za procjenu hrapavosti. Vjerojatnost poskliznuća u suhim uvjetima za sve je ispitivane drvene podove bila niska. Vlaženje površine vodom i uljem smanjilo je otpornost na klizanje površinski obrađenih podova od hrastovine i bukovine. Utvrđena je velika negativna korelacija između otpornosti na klizanje na suhoj površini drvenih podova i parametara hrapavosti R_a, R_z, R_t i R_p te pozitivna korelacija između otpornosti na klizanje na podovima zalivenim vodom i parametara hrapavosti R_a, R_z, R_t i R_p. Nadalje, korelacije između parametara hrapavosti R_a, R_t, R_p i R_z i otpornosti na klizanje bile su vrlo slične. Parametri hrapavosti jače su korelirali s otpornošću na klizanje na suhim površinama i površinama zalivenim vodom nego s otpornošću na klizanje na površinama zalivenim uljem. Usporedba razredbi vjerojatnosti poskliznuća na površinski obrađenim drvenim podovima dobivena klatnom i na temelju parametra hrapavosti površine R_z pokazala je da je u nekim slučajevima parametar R_z dao precijenjenu*

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vjerojatnost poskliznuća na podovima u mokrim uvjetima. Rezultati potvrđuju prethodna istraživanja prema kojima mjerenja hrapavosti trebaju služiti samo kao vodilja i ne smiju se primjenjivati kao jedini pokazatelj klizavosti drvenih podnih materijala.

Ključne riječi: *klizavost; hrapavost površine; površinski obrađeni drvni podovi; parametri hrapavosti površine*

1 INTRODUCTION
1. UVOD

Slip resistance is an important feature of floor safety and can be defined as the ability of a surface to substantially reduce or prevent the risk of someone slipping (CCAA, 2003). Slip resistance is very complex because the likelihood of slipping is a function of many factors such as floor surface, footwear, environmental conditions, physical condition, etc. Falling mainly happens due to insufficient friction between the shoe sole and the floor, and the coefficient of friction (*COF*) is commonly accepted as an indicator of floor surface slipperiness level. The higher the *COF* is, the higher the degree of anti-slippery (slip resistance effect) will be (Chen *et al*., 2015). According to literature, factors affecting the results of friction measurement are floor materials, floor roughness, liquid/solid contaminants on floor, the groove design of shoes and the friction measurement device used (Liu *et al.*, 2010; Chen *et al*., 2015). There is no generally accepted method of measuring slipperiness.

The Pendulum Tester is the most widely used for measuring the slip resistance of floorings. The device relies on the measurement of the coefficient of friction between a rubber slider and the flooring to assess the resistance to slip (Mijović *et al*., 2008). This method is used in the standard HRN EN 13036-4:2012 and also in Technical Specification HRS CEN/TS 15676:2010 for determining slip resistance of wood flooring.

It has been shown that the coefficient of friction between the shoe sole and the floor is highly dependent on the roughness of the floor surface (Stevenson *et al*., 1989; Chang *et al*., 2001; Li *et al*., 2004).

Chen *et al.* (2015) reported that shoe materials, floor roughness and liquid viscosity significantly affected slip resistance. Various surface roughness parameters were used in scientific papers to determine the relationship between the roughness of the surface and slip resistance.

Stevenson *et al.* (1989) reported that slip resistance of concrete and steel surfaces measured with dynamic friction testing machine increased with the arithmetical average of roughness (Ra).

Good correlation between dynamic friction and roughness parameter R_{pm} of unglazed quarry tiles surfaces was reported by Chang (1998). Chang (1999) used different slipmeters for investigation relationship among slip resistance of unglazed quarry tile, surface roughness and surface conditions. It has been shown that the effect of surface roughness on friction index depended on the slipmeter used, and that rougher surface generally led to a higher friction index. Among 21 evaluated surface roughness parameters, R_{pk} and R_{pm} parameters had the highest correlation with the measured friction indices for wet surfaces and parameters R_a and R_z for dry surfaces. Kim (2018) conducted dynamic friction tests among three shoes and nine floor specimens under different slippery environments and showed significant effects of floor surface roughness parameters (R_a, R_t, R_{tm}) on slip resistance performance under soapy and oily conditions. Li *et al*. (2004) found very high correlation (r=0.932 to 0.99) between the four roughness parameters (R_a, R_{tm}, R_{pm}, R_q) of five floors and the measured coefficient of friction under wet and water-detergent conditions.

Shaw (2007) reported moderate correlation between the roughness parameters R_p, R_t, R_q, R_a, R_z and R_y and wet *PTV* (Pendulum Test Value, closely related to coefficient of dynamic friction) and strong correlation between a particular combination of parameters (R_p /*RS*) and wet pendulum values on a small sample of data from a range of different floor surfaces. This study was extended to over 100 floor samples and it was established that R_p (height of the roughness peak) roughness parameter formed the strongest relationship between any single parameter and wet pendulum values. A strong relationship between wet *PTV* and R_p /*RS* was confirmed with a larger sample of data (Shaw *et al*., 2009). Surface roughness measurements are widely used as a secondary indication of slip resistance potential.

According to UK Health and Safety Executive (HSE- GEIS2, 2012) and Health and Safety Laboratory (HSL), R_z (R_{tm}) is a useful parameter for the prediction of the likely slip resistance of a flooring material under water (and other fluid) contamination.

There have been very limited studies of the effects of wood floor roughness on slip resistance. It has been shown that the relationship between surface micro roughness and slip resistance of the pre-engineered wood floors is complicated and, in some cases, there was disagreement between surface roughness and pendulum results (Loo-Morrey, 2007).

The aim of this paper is to investigate the relationship between the roughness of different wood surfaces treated with oil and polyurethane coating and the slip resistance in dry and water-wet and oily conditions.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 Materials
2.1. Materijali

Radial-textured and tangential-textured samples of oak (*Quercus robur* L.) and beech wood (*Fagus sylvatica* L.) without visible defects were used in this research. Beech and oak are the most common wood species in the production of wooden floors. Before surface finishing, wood samples were conditioned at (23±2) °C and (50±5) % relative humidity (RH) to the constant mass. Wood samples were finished with two-component, solvent-based polyurethane coating (PU) and two-component oil based on isocyanates. Before applying PU coating, wood samples were hand-sanded with paper grit size P80-P120-P180 and wood samples finished with oil were hand-sanded with paper grit size P120. For each type of coating, six samples (three radial-textured and three tangential-textured) were prepared. Coatings were applied with a brush in the amount of 110 g/m^2 for PU coating and 80 g/m^2 for oil per layer. PU coating was applied in three layers (one layer of base coat and two layers of top coat) with a 4 hours drying time between the base and top coat and 24 hours drying time between layers of top coat. The dried base coat was hand-sanded with paper grit size P240. Oil was applied in one coat with wiping excess oil from the wood surface after 15 minutes of application of the oil. Surface finished samples were conditioned for seven days at (23±2) °C and (50±5) % RH before testing of slip resistance and roughness.

2.2 Slip resistance
2.2. Klizavost

The slip resistance measurement was made using pendulum test equipment (Figure 1) and slider 55 on a dry surface, surface contaminated with distilled water and on surface contaminated with linseed oil according to HRS CEN/TS 15676:2010. For each type of wood texture, surface finishing and surface contamination, ten measurements on different places along the grain on the wood surface were made, and average slip resistance was calculated. For measuring slip resistance on wet surface, each measuring place on the sample was moistened evenly with the test fluid and rubber slider was wiped and cleaned after each measurement.

2.3 Surface roughness
2.3. Hrapavost površine

Three samples for each type of wood species, texture and coating were evaluated. Roughness was measured with Surtronic S-126 stylus-type profilometer (Figure 2) manufactured by Taylor-Hobson on ten marked locations on which the slip resistance of the surface was measured. The measuring speed, radius and angle of conical stylus tip were 1 mm/s, 5 mm and 90°, respectively. Roughness measurement was carried out in the direction perpendicular to the wood grain over traverse of 4 mm and roughness profiles were filtered with a cut-off value of 0.8 mm using Gaussian filter. For the evaluation of surface roughness, five parameters were used: R_a, R_t, R_p, R_z and R_{sm}. Definition of used roughness parameters can be seen in Table 1.

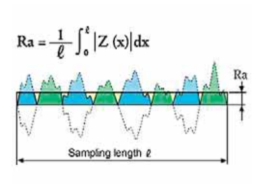
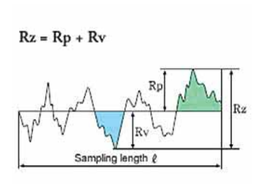
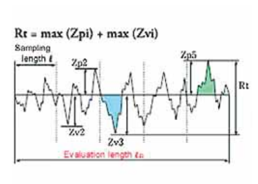
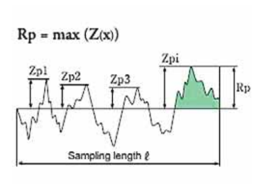
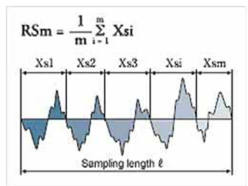
Figure 1 Pendulum test equipment for slip resistance measurement
Slika 1. Uređaj s klatnom za mjerenje klizavosti

Figure 2 Surtronic S-126 stylus-type profilometer
Slika 2. Profilometar Surtronic S-126

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

Results of slip resistance of oak and beech wood samples were generally referred to the slip resistance of the coating on the wood surface (Figure 3). It can be seen that the contamination of the surface with water and linseed oil reduced the slip resistance of finished oak and beech wood. The highest slip resistance was measured on dry surfaces, followed by water-wet surfaces and oil-wet surfaces. Lemon and Griffiths (1997) reported that liquids with higher viscosity required higher levels of surface roughness to provide equivalent levels of slip resistance, as the thickness of a squeezed film formed between the flooring and treads increased as liquids viscosity increased. Polyurethane coating eliminated the influence of structural unevenness of the wood surface on the slippage as it created a dry coating film on the surface. This is the reason for very small differences in slip resistance between oak and beech finished with PU coating. Furthermore, the structural unevenness of the wood surface became prominent on the oil-finished specimens because the oil did not form a film on the wood surface. Thus, the slip resistance of the water-wet surface was higher on the oil-finished samples than on the PU-finished samples. However, the slip resistance on a dry surface was higher on PU-finished samples than on oil-finished samples, which can be attributed to the additives for slip resistance in the coating. Furthermore, oil-finished samples showed a greater difference between slip resistance of water-wet and oil-wet surfaces than PU-finished samples. This could be due to raised wood fibers due to wetting of the surface with water. This is also the reason why the slip resistance of oil-finished beech wood samples contaminated with water was greater than the slip resistance of oil-finished oak wood sam-

Table 1 Description of roughness parameters used in this research according to ISO 4287: 1997
Tablica 1. Definicije parametara hrapavosti primijenjenih u istraživanju prema ISO 4287: 1997

Roughness parameter *Parametar hrapavosti*		**Description** *Definicija*	
R_a	Arithmetical mean deviation of the roughness profile *aritmetičko srednje odstupanje profila hrapavosti*	Arithmetic mean of the absolute ordinate values Z(x) within a sampling length *aritmetička sredina apsolutne vrijednosti ordinate Z(x) unutar referentne duljine*	
R_z	Maximum height of the roughness profile *najveća visina profila hrapavosti*	Sum of height of the largest profile peak height Zp and the largest profile valley depth Zv within sampling length *zbroj visina najvišeg vrha profila Zp i najveće dubine profila Zv unutar referentne duljine*	
R_t	Total height of the roughness profile *ukupna visina profila hrapavosti*	Sum of height of the largest profile peak height Zp and the largest profile valley depth Zv within an evaluation length *zbroj najvišeg vrha profila Zp i najveće dubine profila Zv unutar duljine vrednovanja*	
R_p	Maximum profile peak height *najveća visina vrha profila*	Largest profile peak height Zp within a sampling length *najveća visina vrha profila Zp unutar referentne duljine*	
R_{Sm}	Mean width of profile elements of the roughness profile *srednja širina elemenata profila hrapavosti*	Mean value of the profile element widths Xs within a sampling length *srednja vrijednost širine elemenata profila Xs unutar referentne duljine*	

ples contaminated with water. Beech wood has a higher swelling coefficient than oak, so the fibers on beech wood are more raised than on oak wood. Differences in slip resistance due to the texture of wood were relatively small, and a greater difference in slip resistance between radial-textured and tangential-textured samples could only be seen on oil-wet surface of oak wood samples. It can be assumed that oil-wet surface of tan-

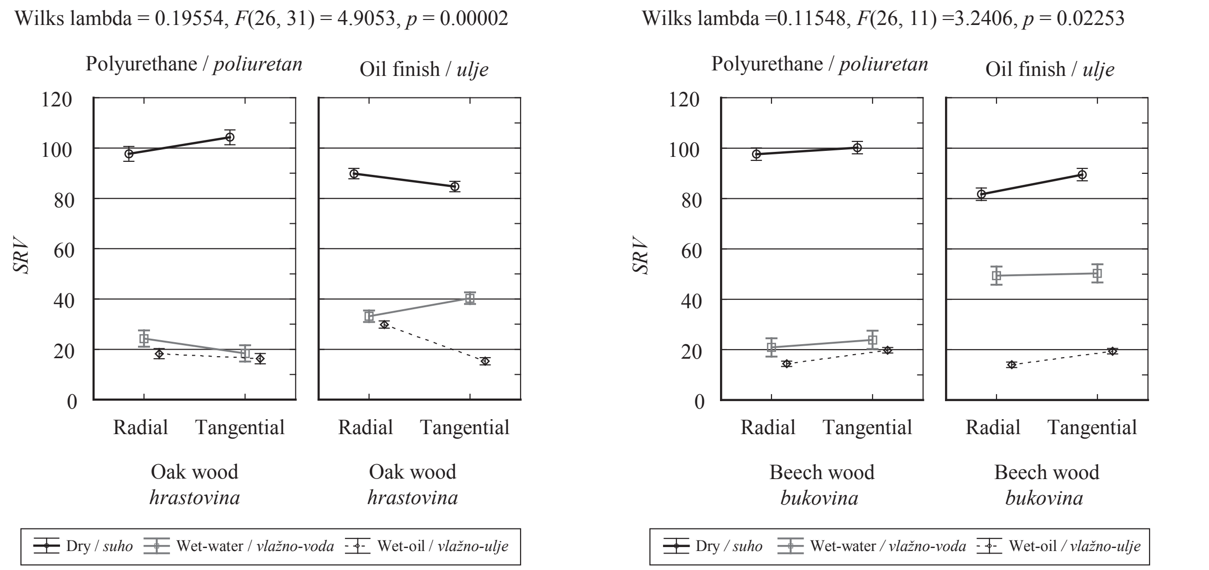


Figure 3 Slip resistance value (*SRV*) of oak and beech wood samples finished with polyurethane coatings and oil
Slika 3. Vrijednosti klizavosti (*SRV*) uzoraka bukovine i hrastovine površinski obrađenih poliuretanskim lakom i uljem

Table 2 Roughness parameters of surface finished oak and beech wood samples
Tablica 2. Parametri hrapavosti površinski obrađenih uzoraka hrastovine i bukovine

Sample / *Uzorak*	R_a, mm	R_z, mm	R_p, mm	R_t, mm	R_{sm}, mm
Oak-PU-radial / *hrastovina - PU - blistača*	0.4[a] (0,17)[b]	2.4 (0.73)	1.6 (0.42)	4.5 (2.05)	395.8 (244.31)
Oak-PU-tangential / *hrastovina - PU - bočnica*	0.3 (0.11)	2.0 (0.77)	1.2 (0.33)	3.7 (2.49)	267.9 (81.25)
Oak-PU-radial / *hrastovina - ulje - blistača*	4.7 (1.08)	26.2 (7.36)	11.3 (2.39)	48.9 (15.02)	177.3 (25.88)
Oak-PU-tangential / *hrastovina - ulje - bočnica*	3.4 (1.22)	19.7 (6.96)	8.5 (2.47)	28.3 (9.44)	159.1 (20.96)
Beech-PU-radial / *bukovina - PU - blistača*	0.4 (0.09)	2.1 (0.37)	1.2 (0.23)	2.9 (0.81)	270,4 (89.01)
Beech-PU-tangential / *bukovina - PU - bočnica*	0.3 (0.07)	2.1 (0.37)	1.2 (0.24)	3.4 (0.98)	235.1 (61.95)
Beech-PU-radial / *bukovina - ulje - blistača*	2.2 (0.38)	16.2 (2.53)	5.9 (1.10)	22.5 (3.9)	104.6 (16.31)
Beech-PU-tangential / *bukovina – ulje - bočnica*	3.9 (1.47)	23.7 (6.26)	9.6 (2.22)	32.7 (8.4)	124.7 (15.97)

[a] The mean value is the result of 30 measurements. / *Srednja vrijednost od 30 mjerenja.*
[b] Values in parentheses are standard deviations. / *U zagradama su standarne devijacije.*

gential-textured oak wood samples had a lower slip resistance compared to oil-wet surface of radial-textured wood samples due to a higher share of latewood, which has smaller pores compared to earlywood.

Table 2 shows the means and standard deviations of roughness measurements of the eight finished wood floor surfaces. For the R_a roughness parameter, there are no variations of means among different wood species finished with PU coating. The average R_a value of the oil finished radial oak wood surface is greater than the average R_a value of the oil finished beech wood surface, which can be explained by the differences in the anatomical structure of these two types of wood.

For R_z and R_t the differences between the oil finished surfaces and those finished with polyurethane are much greater. Since oil is a penetrating finish that does not form a film on the surface, the substrate itself greatly affects the results of roughness measurements. The results of measuring the roughness of radial and tangential surfaces differ much more for oil finished samples than for polyurethane finished samples. The average R_p values of the radial and tangential wood surfaces do not differ much for the surfaces finished with polyurethane coating, while for the oiled surfaces there is a difference in the values of R_p between the radial and tangential surfaces. It can be seen from Table 1 that the average R_{sm} values are much higher for polyurethane finished wood surfaces than for oil finished surfaces. Roughness parameter R_{sm} is the measure of the spacing between the peaks of the surface profile and the R_{sm} values are influenced by the thickness of the film, that is, the application of the polyurethane coating.

Spearman rank correlation coefficients between slip resistance and roughness parameters of surface finished beech and oak wood samples are presented in Tables 3 and 4. It can be seen that there is a significant negative correlation between slip resistance of a dry surface and the type of coating. This was expected because the PU coating forms a film on the wood surface, while the wood absorbs oil and thus the structure of the oil-finished wood surface also affects the slip resistance. Furthermore, a strongly negative correlation between slip resistance of dry surfaces of oak and beech wood and roughness parameters R_a, R_t, R_p and R_z was observed. However, the correlation of slip resistance of a dry surface with R_{sm} parameter was significant and negative and was higher on beech than on oak wood. This can be attributed to the higher standard deviation

Table 3 Spearman rank correlation coefficients between slip resistance and surface roughness of surface finished beech wood
Tablica 3. Spearmanov koeficijent korelacije između klizavosti i hrapavosti površinski obrađene bukovine

Variable *Varijabla*	**Texture** *Tekstura*	**Type of coating** *Vrsta premaza*	**SVR Dry** *SVR suho*	**SVR Wet-water** *SVR mokro - voda*	**SVR Wet-oil** *SVR mokro - ulje*	R_a	R_z	R_t	R_p	R_{Sm}
Texture / *tekstura*	1.000	0.000	0.298	0.126	0.864*	0.197	0.205	0.265	0.230	0.080
Type of coating *vrsta premaza*	0.000	1.000	-0.841*	0.868*	-0.020	0.874*	0.874*	0.868*	0.885*	-0.754*
SVR Dry *SVR suho*	0.298	-0.841*	1.000	-0.670*	0.316*	-0.639*	-0.646*	-0.638*	-0.606*	0.610*
SVR Wet-water *SVR mokro - voda*	0.126	0.868*	-0.670*	1.000	0.069	0.795*	0.789*	0.783*	0.760*	-0.585*
SVR Wet-oil *SVR mokro - ulje*	0.864*	-0.020	0.316*	0.069	1.000	0.134	0.126	0.202	0.178	0.016
R_a	0.197	0.874*	-0.639*	0.795*	0.134	1.000	0.980*	0.962*	0.943*	-0.509*
R_t	0.265	0.868*	-0.638*	0.782*	0.202	0.962*	0.976*	1.000	0.934*	-0.541*
R_p	0.230	0.885*	-0.606*	0.760*	0.178	0.943*	0.954*	0.934*	1.000	-0.606*
R_z	0.205	0.874*	-0.646*	0.789*	0.126	0.980*	1.000	0.976*	0.954*	-0.512*
R_{Sm}	0.080	-0.754*	0.601*	-0.585*	0.016	-0.509*	-0.512*	-0.541*	-0.606*	1.000

*Correlation is significant at p<0.05000. / *Korelacija je značajna pri p<0.05000.*

Table 4 Spearman rank correlation coefficients between slip resistance and surface roughness of surface finished oak wood
Tablica 4. Spearmanov koeficijent korelacije između klizavosti i hrapavosti površinski obrađene hrastovine

Variable *Varijabla*	**Texture** *Tekstura*	**Type of coating** *Vrsta premaza*	**SVR Dry** *SVR suho*	**SVR Wet-water** *SVR mokro - voda*	**SVR Wet-oil** *SVR mokro - ulje*	R_a	R_z	R_t	R_p	R_{Sm}
Texture / *tekstura*	1.000	0.000	-0.167	0.197	-0.732*	-0.092	-0.195	-0.069	-0.091	-0.128
Type of coating *vrsta premaza*	0.000	1.000	-0.757*	0.745*	0.288*	0.818*	0.817*	0.819*	0.818*	-0.432*
SVR Dry *SVR suho*	-0.167	-0.757*	1.000	-0.733*	-0.034	-0.603*	-0.513*	-0.616?	-0.579*	0.319*
SVR Wet-water *SVR mokro - voda*	0.197	0.745*	-0.733*	1.000	-0.027	0.567*	0.484*	0.578*	0.553*	-0.229
SVR Wet-oil *SVR mokro - ulje*	-0.732*	0.288*	-0.034	-0.027	1.000	0.365*	0.431*	0.334*	0.336*	0.076
R_a	-0.092	0.818*	-0.603*	0.567*	0.365*	1.000	0.945*	0.981*	0.988*	-0.162
R_t	-0.195	0.817*	-0.513*	0.484*	0.431*	0.945*	1.000	0.935*	0.954*	-0.240
R_p	-0.069	0.819*	-0.616*	0.578*	0.334*	0.981*	0.935*	1.000	0.981*	-0.184
R_z	-0.091	0.818*	-0.579*	0.553*	0.336*	0.988*	0.954*	0.981*	1.000	-0.198
R_{Sm}	-0.128	-0.432*	0.319*	-0.229	0.076	-0.162	-0.240	-0.184	-0.198	1.000

*Correlation is significant at $p<0.05000$. / *Korelacija je značajna pri* $p<0.05000$.

of roughness parameters R_{sm} on oak than on beech wood (Table 2).

Slip resistance of water-wet surface had a positive correlation with roughness parameters R_a, R_t, R_p and R_z on beech and oak wood, and this correlation was higher on beech than on oak wood. Furthermore, a significant negative correlation of slip resistance on water-wet surface and roughness parameter R_{sm} on beech wood was found, whereas on oak wood this correlation was not significant. It can also be seen that the correlation of slip resistance and roughness parameters R_a, R_t, R_p and R_z was higher on water-wet beech wood surface than on a dry surface. For slip resistance on oil-wet surface, no correlation was found with the investigated roughness parameters on beech wood, while on oak wood there was a small correlation between slip resistance on oil-wet surface and roughness parameters R_a, R_t, R_p and R_z. However, slip resistance on oil-wet surface was in a strong correlation with wood texture on beech and oak wood. The obtained correlation between the parameter R_a and the slip resistance on water-wet and oil-wet surfaces is less than the correlation obtained by Lie *et al*. (2004) on the ceramic floors.

According to the results shown in Table 3, it can be seen that the correlations between roughness parameters R_a, R_t, R_p and R_z and slip resistance are very similar and it can be said that no roughness parameter deviate. Furthermore, it can be seen that the roughness parameters correlated more strongly with the slip resistance on dry and water-wet surfaces than with the slip resistance on oil-wet surface.

The technical specification (HRN CEN/TS 1567) prescribes a pendulum test for determining slip resistance of wood flooring but does not provide slip resistance ratings (or does not provide interpretation of slip resistance data, or classification). The results of slip resistance measurements and R_z roughness measurements in this study were interpreted according to the UKSRG Guidelines (HSE-GEIS2, 2012). The interpretation of pendulum results is shown in Table 5 (HSE-GEIS2, 2012). According to UK Slip Resistance Group, Rz roughness parameter gives a good indication of floor slipperiness in water contaminated conditions. However, the roughness measurement should be considered as a complementary measurement to be used in conjunction with pendulum test values. Slip potential classification, based on R_z microroughness values, is shown in Table 6 (HSE-GEIS2, 2012).

Pendulum results on dry and wet wood surfaces and slip potential in dry and wet conditions are given in

Table 5 Slip potential classification, based on pendulum test value (PTV)[a] (HSE-GEIS2, 2012)
Tablica 5. Razradba vjerojatnosti poskliznuća na temelju ispitivanja klatnom (PTV)[a] (HSE-GEIS2, 2012.)

Pendulum test value *Vrijednosti klizavosti dobivene klatno*m	**Potential for slip** *Vjerojatnost poskliznuća*
24 and below	High / *velika*
25 to 35	Moderate / *umjerena*
36 and above	Low / *mala*

[a]Also known as slip resistance value (*SRV*) / *također poznata kao vrijednost otpora klizanju (SRV)*

Table 6 Slip potential classification, based on R_z microroughness values (applicable for water-wet pedestrian areas) (HSE-GEIS2, 2012)
Tablica 6. Razradba vjerojatnosti poskliznuća na temelju R_z vrijednosti mikrohrapavosti (odnosi se na vodom zalivene površine za hodanje) (HSE-GEIS2, 2012)

R_z (R_{tm}) **surface roughness** R_z (R_{tm}) *hrapavost površine*	**Potential for slip** *Vjerojatnost poskliznuća*
Below 10	High / *velika*
Between 10 and 20	Moderate / *umjerena*
Above 20	Low / *mala*

Table 7 Slip potential classification, based on pendulum test values (*PTV*)[a] and R_z microroughness values (applicable for water-wet pedestrian areas)
Tablica 7. Vjerojatnost poskliznuća prema testu klatnom (*PTV*)[a] i R_z vrijednosti mikrohrapavosti (odnosi se na vodom zalivene površine za hodanje)

Sample *Uzorak*	**Dry (*SRV*)** *Suho (SRV)*	**Slip potential** *Vjerojatnost poskliznuća*	**Water (*SRV*)** *Voda (SRV)*	**Slip potential** *Vjerojatnost poskliznuća*	**Oil** (*SRV*) *Ulje (SRV)*	**Slip potential** *Vjerojatnost poskliznuća*	**Roughness R_z, mm** *Hrapavost R_z, mm*	**Slip potential in wet-water predicted by R_z** *Vjerojatnost poskliznuća u mokrim uvjetima procijenjena na temelju parametra R_z*
Oak-PU-radial *hrastovina - PU - blistača*	97.7 (4.08)	Low *mala*	24.3 (6.23)	High *velika*	18.3 (2.45)	High *velika*	2.4 (0.73)	High *velika*
Oak-PU-tangential *hrastovina - PU - bočnica*	104.3 (4.29)	Low *mala*	18.4 (3.29)	High *velika*	16.3 (4.10)	High *velika*	2.0 (0.77)	High *velika*
Oak-PU-radial *hrastovina - ulje - blistača*	96.6 (5.5)	Low *mala*	28.1 (2.84)	Moderate *umjerena*	30.0 (3.44)	Moderate *umjerena*	26.2 (7.36)	Low *mala*
Oak-PU-tangential *hrastovina - ulje - bočnica*	85.2 (4.31)	Low *mala*	29.8 (1.94)	Moderate *umjerena*	14.0 (1.79)	High *velika*	19.7 (6.96)	Moderate *umjerena*
Beech-PU-radial *bukovina - PU - blistača*	97.6 (4.05)	Low *mala*	20.9 (6.93)	High *velika*	14.4 (1.20)	High *velika*	2.1 (0.37)	High *velika*
Beech-PU-tangential *bukovina - PU - bočnica*	100.2 (2.56)	Low *mala*	23.9 (6.88)	High *velika*	19.8 (1.78)	High *velika*	2.1 (0.37)	High *velika*
Beech-PU-radial *bukovina - ulje - blistača*	81.7 (4.56)	Low *mala*	49.4 (3.93)	Moderate *umjerena*	14.0 (1.79)	High *velika*	16.2 (2.53)	Moderate *umjerena*
Beech-PU-tangential *bukovina - ulje - bočnica*	89.5 (3.04)	Low *mala*	50.3 (2.05)	Moderate *umjerena*	19.4 (1.56)	High *velika*	23.7 (6.26)	Low *mala*

[a]Also known as slip resistance value (*SRV*) / *također poznata kao vrijednost otpora klizanju (SRV)*

Table 7. Mean average values of the R_z parameter and slip potential in water-wet conditions predicted by R_z parameter (according to UKSRG Guidelines) are also given in Table 7. It can be seen that slip potential in dry conditions was low for all studied finished wood floors. The oil-finished wood floors exhibited moderate slip potential in water-wet conditions, while PU-finished wood floors showed high slip potential in water-wet conditions. Kim (2018) showed that the floor finishes require different levels of surface roughness for different types of environmental conditions to effectively control slip potential. Slip potential in oily conditions was shown to be high for all finished wood surfaces except oiled oak wood radial surfaces, where slip resistance was shown to be moderate. Comparisons of the slip potential classifications of finished wood floors based on pendulum data and based on R_z surface roughness parameters show that in two cases the R_z parameter appears to overestimate the slip potential of the floors in wet conditions. This result, as well as results reported by Lo-Morrey (2007), indicates that the parameter R_z is not recommended as the sole selection criteria for selecting a new floor. The parameter R_z should be considered together with the pendulum measurements in both wet and dry conditions before making a specification decision.

4 CONCLUSIONS
4. ZAKLJUČAK

According to the results obtained in this study, it can be concluded that contamination of the surface with water and linseed oil reduces the slip resistance of finished oak and beech flooring. Furthermore, the viscosity of the contaminant has a greater effect on reducing the slip resistance on flooring finished with penetrating coating materials, while on flooring finished with film-forming coating materials, the viscosity of contaminant has little effect on changing the slip resistance. Based on the results of the roughness measurement, it can be concluded that the oil-finished surface has a greater influence on the roughness than the surface finished with polyurethane varnish. Moreover, the correlations between roughness parameters R_a, R_t, R_p and R_z and slip resistance are very similar and the roughness parameters correlate more strongly with the slip resistance on dry and water-wet surfaces than with the slip resistance on oil-wet surface. According to

HSE-GEIS2 (2012), the slip potential in dry conditions is low for oil and PU-finished wood floors, while the oil-finished wood floors exhibited moderate slip potential in water-wet conditions and PU-finished wood floors showed high slip potential in water-wet conditions. Furthermore, slip potential in oily conditions was shown to be high for all finished wood surfaces except oiled oak wood radial surfaces, where slip resistance was shown to be moderate. The slip potential based on R_z surface roughness parameter indicates that the parameter R_z should be considered together with the pendulum measurements in both wet and dry conditions before making a specification decision.

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